



DRAFT INTERNATIONAL STANDARD ISO/DIS 15390

ISO/TC 20/SC 14

Secretariat: ANSI

Voting begins on
2002-08-01

Voting terminates on
2003-01-01

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Space environment (natural and artificial) — Model of radiation impact by galactic cosmic rays

Environnement spatial (naturel et artificiel) — Modèle d'impact de rayonnement par rayons cosmiques galactiques

ICS 49.140

In accordance with the provisions of Council Resolution 15/1993 this document is circulated in the English language only.

Conformément aux dispositions de la Résolution du Conseil 15/1993, ce document est distribué en version anglaise seulement.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.

Pour accélérer la distribution, le présent document est distribué tel qu'il est parvenu du secrétariat du comité. Le travail de rédaction et de composition de texte sera effectué au Secrétariat central de l'ISO au stade de publication.

THIS DOCUMENT IS A DRAFT CIRCULATED FOR COMMENT AND APPROVAL. IT IS THEREFORE SUBJECT TO CHANGE AND MAY NOT BE REFERRED TO AS AN INTERNATIONAL STANDARD UNTIL PUBLISHED AS SUCH.

IN ADDITION TO THEIR EVALUATION AS BEING ACCEPTABLE FOR INDUSTRIAL, TECHNOLOGICAL, COMMERCIAL AND USER PURPOSES, DRAFT INTERNATIONAL STANDARDS MAY ON OCCASION HAVE TO BE CONSIDERED IN THE LIGHT OF THEIR POTENTIAL TO BECOME STANDARDS TO WHICH REFERENCE MAY BE MADE IN NATIONAL REGULATIONS.

Copyright notice

This ISO document is a Draft International Standard and is copyright-protected by ISO. Except as permitted under the applicable laws of the user's country, neither this ISO draft nor any extract from it may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, photocopying, recording or otherwise, without prior written permission being secured.

Requests for permission to reproduce should be addressed to either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

Reproduction may be subject to royalty payments or a licensing agreement.

Violators may be prosecuted.

Contents

Page

Foreword	iv
Introduction.....	v
1 Scope.....	1
2 Terms and definitions	1
3 Principles of the model.....	1
4 GCR rigidity and energy spectra	2
 4.1 General	2
 4.2 GCR particle rigidity spectra.....	2
 4.2 GCR energy spectra.....	3

Tables

Table 1 — Parameters of GCR rigidity spectra for particles $Z \leq 28$	4
Table 2 — Parameters and GCR rigidity spectra for particles $Z \geq 29$	5

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

ISO 15390 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Space environment (natural and artificial) — Model of radiation impact by galactic cosmic rays

1 Scope

This International Standard is intended for estimating the radiation impact of galactic cosmic rays (GCR) on hardware and on biological and other objects when in space. The standard can also be used in scientific research to generalize the available experimental evidence for GCR fluxes. The standard establishes the model parameters and characteristics of variations in the 10^1 - 10^5 MeV GCR particles (electrons, protons, and Z = 2-92 nuclei in the near-earth space beyond the Earth's magnetosphere.

2 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

2.1

galactic cosmic rays

GCR

high-energy charged particle fluxes penetrating the heliosphere from local interstellar space

2.2

Wolf number

W

$W = 10g+f$, where g is sunspot group number; f is the total sunspot number on the Sun's visible disk

2.3

rigidity spectrum

$[\Phi_i(R)]$

rigidity distribution of cosmic ray particle fluxes

2.4

energy spectrum

$[F_i(E)]$

energy distribution of cosmic ray particle fluxes

3 Principles of the model

3.1 The model describes the variations of GCR fluxes due to variations in solar activity and in the large-scale heliospheric magnetic field (the Sun's polar magnetic field) throughout 22-year cycles.

3.2 The angular distribution of galactic cosmic ray fluxes in the Earth orbit beyond the Earth's magnetosphere is to be isotropic.

3.3 Solar activity is characterized by 12-month averages of Wolf numbers (sunspot numbers) \bar{W} .

3.4 The variations of the large-scale heliospheric magnetic field are assumed to be proportional to the variations of the Sun's polar magnetic field whose intensity and polarity are taken to be dependent on solar activity and on whether a given solar cycle is even or odd:

$$M[\bar{W}(t), n] = (-1)^{n-1} \times S \times \left\{ 1 - \left[\frac{\bar{W}(t) - W_n^{\max}}{W_n^{\max} - W_n^{\min}} \right]^{2.7} \right\} \quad (1)$$

where $S=1$ at $t - t_n^\pm \geq 0$ (otherwise, $S=-1$); t_n^\pm is the sign reversal moment of the polar magnetic field in the n -th solar cycle identified with solar maximum; W_n^{\max} ; W_n^{\min} are the least solar activity levels that border the n -th solar cycle.

3.5 The dynamics of the large-scale GCR modulation is characterized by the effective modulation potential of the heliosphere, $R_o(t, R)$, (for particles of rigidity R at a given moment t) calculated as

$$R_o[\bar{W}[t - \Delta t(n, R, t)]] = 0.37 + 3 \times 10^{-4} \times W^{1.45}[t - \Delta t(n, R, t)] \quad (2)$$

3.6 The lag, $\Delta T(n, R, t)$, of GCR flux variations relative to solar activity variations is taken to depend on magnetic rigidity, R , of particles, on whether a solar cycle is odd or even (n), and on solar cycle phase:

$$\Delta T(R, n, t) = 0.5[T_+ + T_-(R)] + 0.5[T_+ - T_-(R)] \times \tau(\bar{W}) \quad (3)$$

where the lag amplitude is independent of particle rigidity in even cycles (T_+):

$$T_+ = 15 \text{ months} \quad (4)$$

$$\text{and is } T_-(R) = 7.5 \times R^{-0.45} \text{ months} \quad (5)$$

in odd cycles (T_-). The time function of the lag variations from (3) is taken to be

$$\tau(\bar{W}) = (-1)^n \times \left[\frac{\bar{W}(t - \delta_w t) - W_n^{\min}}{W_n^{\max}} \right]^{0.2} \quad (6)$$

where $\delta_w t = 16$ months.

4 GCR rigidity and energy spectra

4.1 General

In terms of the GCR model, the particle flux rigidity and energy spectra are calculated consecutively.

4.2 GCR particle rigidity spectra

4.1.1 GCR particle rigidity spectra $\Phi_i(R, t)$ ($\text{s.m}^2.\text{sr.GV}^{-1}$) for particles of rigidity R at moment t are calculated as

$$\Phi_i(R, t) = \frac{C_i \times \beta^{\alpha_i}}{R^{\gamma_i}} \times \left[\frac{R}{R + R_o(R, t)} \right]^{\Delta_i(R, t)} \quad (7)$$

where $\Delta_i(R, t)$ is a dimensionless parameter calculated as

$$\Delta_i(R, t) = 5.5 + 1.13 \frac{Z_i}{|Z_i|} M(W, n) \times \frac{\beta R}{R_o(R, t)} \exp\left(-\frac{\beta R}{R_o(R, t)}\right) \quad (8)$$

Here, β is particle velocity-to-luminal velocity ratio

$$\beta = \frac{R}{\sqrt{R^2 + \left(\frac{A_i m_i}{Z_i}\right)^2}} \quad (9)$$

where A_i, Z_i are particle mass number and charge (see Table 1 and Table 2); C_i, α_i, γ_i are parameters of non-modulated rigidity spectrum of i-specie particles.

For particles with $Z \leq 28$ see Table 1.

For particles with $Z \geq 29$, $\alpha_i = \alpha_{26}$ and $\gamma_i = \gamma_{26}$, C_i , is calculated from equation $C_i = C_{26} \frac{C_i}{C_{26}}$, where $\frac{C_i}{C_{26}}$ data is found in Table 2.

m_i is particle rest mass, namely,

$m_e = 0.51$ MeV for electrons,

$m_p = 0.938$ GeV for protons,

$m_{z \geq 2} = 0.939$ GeV/nucleon for nuclei.

4.1.2 The standard deviations of the ($\sigma_{\Phi_i(R,t)}$) values are calculates as

$$\sigma_{\Phi_i(R,t)} = \Phi_i(R, t) \times \sqrt{\left(\frac{\sigma_{D_i}}{C_i}\right)^2 + \frac{0.08}{\left[1 + \frac{R}{R_o(R, t)}\right]^2}} \quad (10)$$

4.2 GCR energy spectra

4.2.1 The energy spectra $F_i(E, t)$ ($\text{s.m}^2.\text{sr.GeV}^{-1}$) of GCR particles of energy E at moment t are calculated as

$$F_i(E, t) = \Phi_i(R, t) \frac{A_i}{|Z_i|} \frac{10^{-3}}{\beta} \quad (11)$$

For particles with $A_i = 1$, the units are ($\text{s.m}^2.\text{sr.MeV}^{-1}$).

For particles with $A_i \geq 2$, the units are ($\text{s.m.sr.MeV/nucleon}^{-1}$)

4.2.2 With prescribed rigidity R of GCR particles, the kinetic energy E, in GeV (GeV/nucleon for nuclei), is calculated as

$$E = -m_i + \sqrt{m_i^2 + \left(\frac{Z_i}{A_i} R\right)^2} \quad (12)$$

4.2.3 With prescribed kinetic energy of particles, the rigidity R and the relative velocity β of the particles are calculated as

$$R = \frac{A_i}{Z_i} \sqrt{E(E + 2m_i)} \quad (13)$$

$$\beta = \frac{\sqrt{E(E + 2m_i)}}{E + m_i} \quad (14)$$

4.2.4 Standard deviations of the calculated ($\sigma_{F_i(E,t)}$) values are calculated as

$$\sigma_{F_i(E,t)} = \frac{\sigma_{\Phi_i(R,t)}}{\Phi_i(R,t)} \cdot F_i(E,t) \quad (15)$$

Table 1 — Parameters of GCR rigidity spectra for particles Z ≤ 28

Z	Particle	A _i	C _i ± σ _{C_i}	γ _i	α _i
-1	e	1,0	170	-	γ _e [*]
1	H	1,0	(1,85 ± 0,13) 10 ⁴	2,74 ± 0,02	2,85 ± 0,02
2	He	4,0	(3,69 ± 0,22) 10 ³	2,77 ± 0,02	3,12 ± 0,02
3	Li	6,9	19,5 ± 1,5	2,82 ± 0,02	3,41 ± 0,11
4	Be	9,0	17,7 ± 1,3	3,05 0,02	4,30 ± 0,12
5	B	10,8	49,2 ± 1,6	2,96 ± 0,01	3,93 ± 0,05
6	C	12,0	103,0 ± 3,0	2,76 ± 0,01	3,18 ± 0,04
7	N	14,0	36,7 1,2	2,89 ± 0,01	3,77 ± 0,05
8	O	16,0	87,4 2,1	2,70 ± 0,01	3,11 ± 0,04
9	F	19,0	3,19 ± 0,28	2,82 ± 0,03	4,05 ± 0,06
10	Ne	20,2	16,4 ± 0,70	2,76 ± 0,01	3,11 ± 0,07
11	Na	23,0	4,43 ± 0,28	2,84 ± 0,02	3,14 ± 0,09
12	Mg	24,3	19,3 ± 0,70	2,70 ± 0,01	3,65 ± 0,27
13	Al	27,0	4,17 ± 0,22	2,77 ± 0,02	3,46 ± 0,21
14	Si	28,1	13,4 ± 0,50	2,66 ± 0,01	3,00 ± 0,10
15	P	31,0	1,15 ± 0,04	2,89 ± 0,01	4,04 ± 0,41
16	S	32,1	3,06 ± 0,12	2,71 ± 0,02	3,30 ± 0,22

Z	Particle	A_i	$C_i \pm \sigma_{C_i}$	γ_i	α_i
17	Cl	35,4	$1,30 \pm 0,08$	$3,00 \pm 0,04$	$4,40 \pm 0,30$
18	Ar	39,9	$2,33 \pm 0,07$	$2,93 \pm 0,01$	$4,33 \pm 0,21$
19	K	39,1	$1,87 \pm 0,05$	$3,05 \pm 0,01$	$4,49 \pm 0,20$
20	Ca	40,1	$2,17 \pm 0,06$	$2,77 \pm 0,01$	$2,93 \pm 0,16$
21	Sc	44,9	$0,74 \pm 0,02$	$2,97 \pm 0,01$	$3,78 \pm 0,19$
22	Ti	47,9	$2,63 \pm 0,08$	$2,99 \pm 0,01$	$3,79 \pm 0,17$
23	V	50,9	$1,23 \pm 0,04$	$2,94 \pm 0,01$	$3,50 \pm 0,14$
24	Cr	52,0	$2,12 \pm 0,06$	$2,89 \pm 0,01$	$3,28 \pm 0,17$
25	Mn	54,9	$1,14 \pm 0,05$	$2,74 \pm 0,02$	$3,29 \pm 0,27$
26	Fe	55,8	$9,32 \pm 0,24$	$2,63 \pm 0,01$	$3,01 \pm 0,07$
27	Co	58,9	$0,10 \pm 0,08$	2,63	$4,25 \pm 0,79$
28	Ni	58,7	$0,49 \pm 0,02$	$2,63 \pm 0,01$	$3,52 \pm 0,28$
NOTE 1 In the case of Z > 2 GCR nuclei, the C_i, γ_i, α_i values are for a mixture of the respective isotopes.					
NOTE 2 Atomic weights corresponding to the natural elemental abundances are taken to be mass numbers A_i for Z > 2 nuclei in conformity with the periodic system chart. This is within the model accuracy.					
NOTE 3 In the case of electrons, the parameter $\gamma_e = 3.0 - 1.4 \exp\left(\frac{R}{R_e}\right)$, where $R_e = 1$ GeV.					

Table 2 — Parameters and GCR rigidity spectra for particles Z ≥ 29

Z	Particle	A_i	C_i / C_{26}	Z	Particle	A_i	C_i / C_{26}
29	Cu	63,5	6,8E-4	61	Pm	144,2	1,9E-7
30	Zn	65,4	8,8E-4	62	Sm	145,0	1,8E-6
31	Ga	69,7	6,5E-5	63	Eu	150,4	3,1E-7
32	Ge	72,6	1,4E-4	64	Gd	152,0	1,4E-6
33	As	74,9	8,9E-6	65	Tb	157,3	3,5E-7
34	Se	79,0	5,2E-5	66	Dy	158,9	1,4E-6
35	Br	79,9	9,7E-6	67	Ho	162,5	5,3E-7
36	Kr	83,8	2,7E-5	68	Er	164,9	8,8E-7
37	Rb	85,5	8,8E-6	69	Tu	167,3	1,8E-7
38	Sr	87,6	2,9E-5	70	Yb	168,9	8,9E-7
39	Y	88,9	6,5E-6	71	Lu	173,0	1,3E-7
40	Zr	91,2	1,6E-5	72	Hf	175,0	8,1E-7
41	Nb	92,9	2,9E-6	73	Ta	178,5	7,3E-8
42	Mo	95,9	8,1E-6	74	W	180,9	8,1E-7
43	Tc	97,0	9,5E-7	75	Re	183,9	2,8E-7

z	Particle	A_i	C_i / C_{26}	z	Particle	A_i	C_i / C_{26}
44	Ru	101,0	3,1E-6	76	Os	186,2	1,2E-6
45	Rh	102,9	1,6E-6	77	Ir	190,2	7,9E-7
46	Pd	106,4	4,6E-6	78	Pt	192,2	1,5E-6
47	Ag	107,9	1,5E-6	79	Au	195,1	2,8E-7
48	Cd	112,4	4,0E-6	80	Hg	197,0	4,9E-7
49	In	114,8	8,8E-7	81	Tl	200,6	1,5E-7
50	Sn	118,7	4,7E-6	82	Pb	204,4	1,4E-6
51	Sb	121,8	9,9E-7	83	Bi	207,2	7,3E-8
52	Te	127,6	5,7E-6	84	Po	209,0	0
53	J	126,9	1,1E-6	85	At	210,0	0
54	Xe	131,3	2,7E-6	86	Rn	222,0	0
55	Cs	132,9	6,5E-7	87	Fr	223,0	0
56	Ba	137,3	6,7E-6	88	Ra	226,0	0
57	La	138,9	6,0E-7	89	Ac	227,0	0
58	Ce	140,1	1,8E-6	90	Th	232,0	8,1E-8
59	Pr	140,9	4,3E-7	91	Pa	231,0	0
60	Nd	144,2	1,6E-6	92	U	238,0	4,9E-8